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Prediction of maximal oxygen consumption in boys, ages 11 to 14 years: An investigation of field measurements for use in schools

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PREDICTION OF MAXIMAL OXYGEN CONSUMPTION
IN BOYS, AGES 11 TO 14 YEARS: AN INVESTIGATION
OF FIELD MEASUREMENTS FOR USE IN SCHOOLS

A Dissertation
Submitted
In Partial Fulfillment
of the Requirements for the Degree
Doctor of Education

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ABSTRACT

This study investigated the prediction of maximal oxygen consumption in boys, ages 11 to 14 years, from a shuttle walk protocol and other field measurements appropriate to use in school settings. Maximal oxygen consumption was determined in 67 subjects using a treadmill protocol ($\underline{M}$ = 52.3 $ml \cdot kg^{-1} \cdot min^{-1}$, $\underline{SD}$ = 8.4). Subjects performed an 800-yard shuttle walk as fast as possible on a 20-yard course, with elapsed time recorded. Telemetrically measured postwalk heart rate, height, weight, sum of triceps and subscapular skinfold measurements, body mass index, and exercise frequency were also considered as predictors. Multiple linear regression analysis was used to predict maximal oxygen consumption, expressed in both $l \cdot min^{-1}$ and $ml \cdot kg^{-1} \cdot min^{-1}$. Using the shuttle walk time with the postwalk heart rate produced poor predictions ($\underline{R}$ = .25, SEE = 0.612 $l \cdot min^{-1}$; and $\underline{R}$ = .52, SEE = 7.2 $ml \cdot kg^{-1} \cdot min^{-1}$). However, reasonably accurate predictions were obtained simply from physical characteristics, which can be easily measured in school settings. A prediction of absolute maximal oxygen consumption ($l \cdot min^{-1}$) using height, weight, and sum of skinfolds was:

$\dot{V}O_{2max}$ = -1.330 + (0.040 * Height in in.) + (0.017 * Weight in lbs.) - (0.023 * Sum of Skinfolds in mm); $\underline{R}$ = .89, SEE = 0.292 $l \cdot min^{-1}$.

A prediction of relative maximal oxygen consumption ($ml \cdot kg^{-1} \cdot min^{-1}$) using only the sum of skinfolds was:

$\dot{V}O_{2max}$ = 62.528 - (0.446 * Sum of Skinfolds); $r = .80$, SEE = 5.0 $ml \cdot kg^{-1} \cdot min^{-1}$.

Also examined was the accuracy of postexercise self-pulse counting by boys, ages 11 to 14 years. Heart rates were simultaneously measured via self-pulse counting and telemetry, following an 800-yard shuttle walk. A paired t test and a Pearson's product-moment coefficient of correlation were used in the analysis. Self-pulse counting produced significantly lower results than those recorded by telemetry (M_{diff} = 21.0 beats per minute, SD_{diff} = 22.8 beats per minute, $p < .001$). The Pearson's product-moment coefficient of correlation was $r = .68$. It was found, therefore, that 11-to 14-year-old boys could not accurately monitor postexercise heart rate.

CHAPTER I

INTRODUCTION

A national concern is the physical fitness levels of children and youth. A recent United States government document (U.S. Department of Health and Human Services [USDHHS], 1990) identifies objectives to increase physical activity and fitness by the year 2000. Objectives are identified for school age populations which include increasing vigorous physical activity and reducing overweight.

The year 2000 national health objectives emphasize the significance of the schools in the development and maintenance of cardiorespiratory fitness in children and youth. Objectives include the increase in the portion of children and youth who participate in daily physical education programs and an increase in the amount of physical education class time spent on skills and activities that promote lifetime physical activity participation.

The periodic assessment of cardiorespiratory fitness levels in students is important for setting personal fitness goals and designing appropriate individual exercise regimes. It also serves as a motivational factor by providing feedback to students.

The evaluation of an overall physical education program in meeting its cardiorespiratory fitness goals is also an important purpose of periodic testing. Group data may provide a basis for making curriculum changes relative to the selection of specific activities to include in the program, as well as determine total class time devoted to cardiorespiratory fitness.

The method of assessing cardiorespiratory fitness considered most accurate is the direct measurement of oxygen consumption during maximal physical effort. This is usually accomplished by the utilization of a graded exercise test to a point of volitional fatigue, with collection and analysis of expired gases. The direct measurement of oxygen consumption in school populations is impractical, however, due to such factors as test time, expense, equipment, staff training, and student motivation.

Physical education teachers need simple, accurate, and appealing methods for testing cardiorespiratory fitness levels in large numbers of students. Consequently, the estimation of cardiorespiratory fitness levels from field tests has been of interest for many years.

Maximal effort running tests have been developed which predict maximal oxygen consumption from the time taken to run a specific distance (usually of 600 yards or greater). Most running protocols require outdoor test administration, which limits usage during inclement weather conditions. Additionally, because a maximal effort is required for valid results, the tests are not generally appealing to children and youth.

Submaximal effort field tests have also been developed which predict maximal oxygen consumption from heart rate responses measured during or after submaximal bicycling or bench stepping. Schools have not typically acquired sufficient quantities of bicycle ergometers for mass testing purposes. Bench stepping protocols do not allow for individualized pacing. Therefore, difficulties arise when those students with lower functional capacity are unable to complete the testing protocol.

Although many field tests have been developed to estimate cardiorespiratory fitness levels in children and youth, walking tests have not been utilized. Multiple regression equations, which employ walking in combination with heart rate and selected physical growth measurements, have produced correlation coefficients greater than $\underline{R} = .90$ for adult populations (Kline et al., 1987). Previous work by Bonen, Heyward, Cureton, Boileau, and Massey (1979) also produced reasonably reliable and accurate predictions of maximal oxygen consumption for boys using data obtained during a submaximal treadmill walk and height, or simply from age, height, and weight. The use of practical field measurements, including walking, and multiple regression approaches for the prediction of maximal oxygen consumption in children and youth would seem to be a desirable approach.

This investigation sought to develop accurate prediction equations for maximal oxygen consumption from submaximal exercise variables, physical growth characteristics, and exercise habits from a sample of 11- to 14-year-old boys.

Additionally, a sub-problem of this investigation was to determine the accuracy of self-pulse counting by boys during field measurement situations. For reasons of convenience and reasons of cost savings related to expense of heart rate monitors, in school settings, the feasibility of monitoring heart rate by self-reported pulse count was of interest.

Statement of the Problem

The purpose of this study was to investigate the use of a shuttle walk protocol, in combination with other selected field measurements, for predicting maximal oxygen consumption in a volunteer sample of 11- to 14-year-old boys. Specifically, the following predictor variables were considered in the development of the prediction equations: (a) elapsed time on an 800-yard shuttle walk, (b) telemetrically measured postexercise heart rate (following a shuttle walk test), (c) height, (d) weight, (e) sum of triceps and subscapular skinfold thicknesses, (f) body mass index, and (d) days per week of physical activity that elicits sweating and hard breathing for 20 minutes or more. Maximal oxygen consumption was measured during a graded exercise test performed on a motorized treadmill. Stepwise multiple linear regression analysis was used to identify the best prediction equations.

The difference between postexercise heart rate, as measured by self-pulse counting and telemetry, was also analyzed. A paired *t* test and a Pearson's product-moment coefficient of correlation were employed for this purpose.

Hypotheses

Hypothesis 1

It was hypothesized that a linear combination of predictor variables including: (a) elapsed time on a shuttle walk of 800 yards, (b) telemetrically measured postexercise heart rate (following the shuttle walk test), (c) height, (d) weight, (e) sum of triceps and subscapular skinfold thicknesses, (f) body mass index, and (g) days per week of physical activity that elicits sweating and hard breathing for 20 minutes or more could be identified which will accurately predict maximal oxygen consumption in 11- to 14-year-old boys.

Hypothesis 2

It was hypothesized that, for 11- to 14-year-old boys, there would be no difference in postexercise heart rate as measured by telemetry and self-pulse counting.

Assumptions

For the purposes of this study, the following assumptions were made:

1. Subjects provided accurate and honest answers regarding the number of days per week that they engaged in

physical activity that made them sweat and breathe hard for 20 minutes or more.

2. During treadmill testing, subjects gave an honest effort in exercising to a point of fatigue.

3. During the shuttle walk test, subjects gave an honest effort in walking as fast as they could.

4. Subjects understood the directions for self-pulse counting and followed the recommended procedures during testing.

5. Skinfold measurements were valid measurements of subcutaneous adipose tissue.

Limitations

For the purpose of this study, the following limitations were identified:

1. The peak oxygen consumption value may have been the maximum value determined by subject motivation and may not have been the physiological maximum.

2. Subjects were volunteers and therefore may not have been a representative sample of 11- to 14-year-old boys.

Delimitations

For the purposes of this study, the following delimitations were identified:

1. Subject selection was based on a sample of 11- to 14-year-old boys from Cedar Falls, Waterloo, and the surrounding area.

2. The sample size was delimited to 67 volunteer subjects.

3. The shuttle walk protocol was delimited to the distance of 800 yards, using a 20-yard course.

4. Maximal oxygen consumption measurement was delimited to using a treadmill testing procedure in which workload increments were changed every minute.

Definition of Terms

For the purpose of this study, the following terms were defined:

Cardiorespiratory Fitness Activity: Physical activity in which an individual sweats and breathes hard for a period of 20 minutes or more.

Body Mass Index: Weight, in kilograms, divided by height^2, in meters (Rowland, 1989; Thomas, McKay, & Cutlip, 1976).

Physical Fitness: "As defined by the World Health Organization, physical fitness is the ability to perform muscular work satisfactorily. It is generally thought that the components of physical fitness include cardiorespiratory endurance, muscular strength and endurance, and flexibility" (Bouchard, Shephard, Stephens, Sutton, & McPherson, 1990, p. 6).

> Cardiorespiratory Fitness: The ability to perform large muscle, whole body physical activity of moderate to high intensity for relatively long periods of time. It is the ability of the circulatory and respiratory systems to adjust to vigorous exercise, and to recover from the effect of such exercise. It involves the

> functioning of the heart and lungs, the blood and its capacity to carry oxygen, the blood vessels and capillaries supplying blood to all parts of the body and the muscle cells, which use the oxygen to provide the energy necessary for endurance exercise. (Miller, 1988, p. 143)

Eight-hundred-Yard Shuttle Walk: A walk requiring the walking of 40 lengths consecutively, back and forth, on a 20-yard course.

Maximal Oxygen Consumption: The peak oxygen consumption value achieved during a progressive exercise test. Maximal oxygen consumption (or VO_{2max}) can be expressed in absolute values [i.e., liters per minute ($l \cdot min^{-1}$)] or in relative values [i.e., milliliters per kilogram of body weight per minute ($ml \cdot kg^{-1} \cdot min^{-1}$)].

Physical Activity: "Any bodily movement produced by skeletal muscles and resulting in energy expenditure" (Bouchard et al., 1990, p. 6).

Skinfold Thicknesses: "The thickness of double folds of skin and subcutaneous adipose tissue at specific sites on the body" (Harrison et al., 1988, p. 55).

CHAPTER II

REVIEW OF LITERATURE

This study investigated the use of a shuttle walk protocol, in combination with other selected field measurements, for predicting maximal oxygen consumption in boys, ages 11 to 14 years. Specifically, the following predictor variables were considered in the development of the prediction equations: (a) elapsed time on an 800-yard shuttle walk, (b) telemetrically measured postexercise heart rate (following a shuttle walk test), (c) height, (d) weight, (e) sum of triceps and subscapular skinfold thicknesses, (f) body mass index, and (g) days per week of physical activity that elicits sweating and hard breathing for 20 minutes or more. The difference between postexercise heart rate, as measured by self-pulse counting and telemetry, was also investigated.

In this chapter, cardiorespiratory fitness literature was reviewed as it is related to: (a) health and disease prevention, (b) objectives and status of fitness in children and youth, (c) field testing, and (d) implications in school settings. Literature related to the use of pulse palpation for heart rate monitoring was also reviewed.

Cardiorespiratory Fitness in Disease Prevention

Cardiorespiratory fitness has gained prominence as its relationship with health and disease prevention are explored. A catalyst for the study of physical fitness levels in children and youth has been the underlying belief in the health benefits of physical activity. A government report (U.S. Department of Health and Human Services [USDHHS], 1980) focused on the health implications of physical activity by noting that appropriate physical activity may be valuable for control and improvement of obesity, coronary heart disease, high blood pressure, diabetes, musculo-skeletal problems, respiratory diseases and stress.

Coronary heart disease continues to be the leading cause of death in the United States, accounting for over one-half million deaths annually (Fraser, 1980). Kaplan and Stamler (1983), in review of coronary heart disease, cite studies relating hypertension, elevated blood lipids, cigarette smoking, family history, diabetes, personality traits, oral contraceptive use, obesity, and physical inactivity to increased risk of developing coronary heart disease.

Although coronary heart disease manifests itself in adults, the disease has been shown to originate earlier in life. Young American soldiers examined at autopsy during the Korean War revealed fibrous plaques (Enos, Holmes, & Beyer, 1953). Likewise, McNamara, Molot, Stremple, and Cutting (1971) found fibrous plaques upon examination of Vietnam War casualties.

Investigators have recently provided insight into the relationship between cardiorespiratory fitness activity and coronary heart disease. In a study of male college alumni, Paffenbarger, Hyde, Wing, and Steinmetz (1984) showed that habitual postcollege exercise predicted low coronary heart disease and is independent of contrary lifestyle elements such as smoking, weight gain, high blood pressure, and adverse family history. Paffenbarger, Hyde, Wing, and Hsieh (1986) also reported that death rates declined steadily as energy expended daily on physical activity increased.

Using treadmill exercise testing to measure cardiorespiratory fitness, Blair et al. (1989) studied cardiorespiratory fitness and risk of all-cause and cause-specific mortality in 10,224 men and 3,120 women and found that age adjusted all-cause mortality rates declined across physical fitness quintiles for both men and women. These trends remained after adjustment for smoking, cholesterol level, systolic blood pressure, family history of coronary heart disease, and fasting blood glucose level. In addition, lower mortality rates in higher fitness categories were seen for both cardiovascular diseases and cancer. Attributable risk estimates for all-cause mortality indicated that low physical fitness was an important risk factor in both men and women.

Youth Fitness: Objectives and Status

Recognizing that the roots of coronary heart disease and other degenerative diseases are related to the development of childhood behavior patterns, youth fitness was identified as a national priority area for health promotion and 1990 objectives for the nation were outlined in a United States government report (USDHHS, 1980). Five national objectives were specified in the area of youth fitness. Three objectives related to 10- to 17-year-olds and were as follows: (a) 60% will attend physical education classes daily, (b) 90% will participate in physical activities that are appropriate for the maintenance of an effective cardiorespiratory system, and (c) 70% will periodically have their fitness levels tested. The two remaining objectives relate to evaluation of health benefits of exercise and the monitoring of physical activity patterns among youth.

In an effort to gather baseline data related to the 1990 national objectives in physical fitness and exercise, the first National Children and Youth Fitness Study (Ross, Dotson, & Gilbert, 1985) examined 10- to 17-year-olds. A summary of the findings suggests that less than 40% of students, in Grades 5 through 12, take physical education daily. Only one-half of boys and girls, in Grades 5 through 12, are achieving at least the minimum amount of "appropriate physical activity," which includes regular, vigorous and prolonged activity essential for an effectively functioning cardiorespiratory system. Appropriate physical activity, as defined and adopted by the National Children and Youth Fitness Study, refers to exercise involving large muscle groups in dynamic movement for periods of 20 minutes or longer, three or more times a week, at an intensity requiring 60% or more of an individual's cardiorespiratory capacity.

In the National Children and Youth Fitness Study, it was reported that youth were fatter than their 1960 counterparts, which were studied by the National Center for Health Statistics. It was also noted that, compared to normative information published by the American Alliance for Health, Physical Education, Recreation and Dance (AAHPERD) in 1980, the performance in the test of cardiorespiratory fitness (i.e., mile run/walk) was slower in the National Children and Youth Fitness Study in 13 of 16 sex/age categories for students, ages 10 to 17 years. Sampling differences are, however, mentioned with a cautionary note. The National Children and Youth Fitness Study suggests that variables related to the physical education programs, community organizations, and physical activity all exert influence on the fitness levels of children, with the exercise-fitness relationships being complex.

As a continued effort in the promotion of health, national health objectives for the year 2000 have been drafted (USDHHS, 1990). The current drafted report specifies national objectives for children and youth in physical activity and fitness. Included as objectives are the following: (a) increase to at least 90% the proportion of children and youth, ages 6 to 17 years, who participate in moderate physical activities three or more days per week for 20 or more minutes per occasion, (b) increase to at least 75% the proportion of children and youth, ages 6 to 17 years, who participate in vigorous physical activities that promote the development and maintenance of cardiorespiratory fitness three or more days per week for 20 or more minutes per occasion, (c) increase to at least 75% the proportion of children and youth, ages 6 to 17 years, who regularly perform physical activities that maintain muscular strength, muscular endurance, and flexibility, (d) reduce overweight among youth, ages 12 to 17 years, to a prevalence of less than 15%, (e) increase to at least 45% the proportion of children and youth, in Grades 1 through 12, who participate in daily physical education programs, and (f) increase to at least 70% the proportion of teachers, who teach physical education, who spend 30% or more of class time on skills and activities that promote lifetime physical activity participation. As is evident, objectives related to children and youth fitness and specifically cardiorespiratory fitness remain important as national objectives, with school programs assuming an important perceived role.

Cardiorespiratory Field Tests

Kline et al. (1987) notes that members of the Harvard Fatigue Laboratory recognized as early as the 1920s the limitations of direct measurement of maximal oxygen consumption, including expense, time requirements, subject motivation, and the impracticality of testing large numbers of subjects. The members of the Harvard Fatigue Laboratory initially attempted to develop submaximal tests to classify individual fitness levels, which included the dragging of a weighted sled and measuring recovery heart rate. Later, the Harvard Step Test was developed by Brouha (1943).

Astrand and Rhyming (1954) first developed a nomogram for the estimation of maximal oxygen consumption based on pulse rate during submaximal work on a bicycle ergometer. Davies (1968), however, cited the potential for error in estimations of this type due to the non-linear and asymptotic heart rate response as one nears maximal oxygen consumption. Cross-validation studies on various populations have produced correlations ranging from $r = .47$ to $r = .92$ (DeVries & Klafs, 1965; Glassford, Baycroft, Sedgwick, & McNab, 1965; Hermiston & Faulkner, 1971; Jessup, Tolson, & Terry, 1974; Teraslinna, Ismail, & MacLeod, 1966).

Fox (1973) studied 87 college age males during bicycle exercise. He reported a correlation of $r = .76$ based on a linear equation relating maximal oxygen consumption ($l \cdot min^{-1}$)

to submaximal heart rate recorded during the 5th minute of exercise at 150 watts.

Mastropaolo (1970) employed a bicycle ergometer protocol with 13 middle age men. It was found that a stepwise multiple regression equation, using several cardiovascular and respiratory variables, produced a correlation of $\underline{R}$ = .93 when predicting maximal oxygen consumption ($l \cdot min^{-1}$).

Siconolfi, Cullinare, Carleton, and Thompson (1982) employed a modified bicycle ergometer test of Astrand and Rhyming (1954) with 50 men and women between the ages of 20 and 70 years. They found that using multiple regression equations, to correct for variations due to age, produced correlations between the measured and estimated maximal oxygen consumption ($l \cdot min^{-1}$) ranging from $\underline{R}$ = .92 to $\underline{R}$ = .93 for the age groups. Knuttgen (1967) tested 95 males and 95 females, ages 15 to 18 years, on a bicycle ergometer. Using weight and the workload which elicited a heart rate of 170 beats per minute he could predict maximal oxygen consumption ($l \cdot min^{-1}$) with reasonable accuracy ($\underline{R}$ = .86 for males and $\underline{R}$ = .71 for females).

Several bench stepping protocols have been developed for testing cardiorespiratory fitness. DeVries and Klafs (1965) validated the original Harvard Step Test and reported a correlation of $\underline{r}$ = .76 between recovery heart rate and maximal oxygen consumption ($ml \cdot kg^{-1} \cdot min^{-1}$). A modification of the Harvard Step Test, the Queens College Step Test (McArdle, Katch, Pechar, Jacobson, & Ruck, 1972), produced a correlation of $\underline{r} = .75$ between recovery heart rate and maximal oxygen consumption ($ml \cdot kg^{-1} \cdot min^{-1}$) in college age women ($\underline{N} = 41$). Johnson and Siegel (1981) tested 34 female college students using six existing bench stepping protocols and reported validity coefficients ranging from $\underline{r} = .42$ to $\underline{r} = .62$.

Several investigators have utilized submaximal treadmill work and other variables to predict maximal oxygen consumption. Hermiston and Faulkner (1971) tested 28 men using a submaximal treadmill walk. Using stepwise multiple regression to develop equations for the prediction of maximal oxygen consumption, they report that age, fat-free weight, heart rate, fraction of carbon dioxide of expired gas, tidal volume at a submaximal work level, and the rate of change of the respiratory exchange ratio produced the best prediction equation for active men. For inactive men, the most accurate prediction equation included age, fat-free weight, respiratory exchange ratio, and tidal volume at the submaximal work level. The correlation between the observed and predicted maximal oxygen consumption ($l \cdot min^{-1}$) was .90, with a reliability coefficient of .91.

Metz and Alexander (1970) tested 60 boys, ranging in age from 12 to 15 years, for the purpose of determining the relationship between maximal oxygen consumption

($ml \cdot kg^{-1} \cdot min^{-1}$) and physical fitness items from the American Association for Health, Physical Education and Recreation (AAHPER) Youth Fitness Test (1965), the McCloy Strength Test (McCloy & Young, 1954) and the Harvard Step Test (Brouha, 1943). The best regression equation for the 12- and 13-year-olds yielded a correlation coefficient of $R = .78$. For 14- and 15-year-olds, the best regression equation yielded a correlation coefficient of $R = .68$. It is interesting to note that the 600-yard run had a correlation coefficient of $r = -.66$ for 12- and 13-year-olds and only $r = -.27$ for 14- and 15-year-olds. Low motivation, as observed by excessive walking, was cited by the authors as a possible explanation for low correlation among the older boys.

Falls, Ismail, and MacLeod (1966) also used the AAHPER Youth Fitness Test (1965) with 87 adult males to predict maximal oxygen consumption. The multiple correlation of the AAHPER items with maximal oxygen consumption ($ml \cdot kg^{-1} \cdot min^{-1}$) was $R = .76$.

Bonen et al. (1979) investigated the prediction of maximal oxygen consumption in boys, ages 7 to 15 years (N = 100). Maximal oxygen consumption ($l \cdot min^{-1}$) was predicted from height, and observations of heart rate and oxygen consumption ($l \cdot min^{-1}$) during the third minute of a treadmill walk. The correlation between the prediction and direct measure of maximal oxygen consumption was $R = .95$. A similar prediction was obtained when the subjects' age, height, and weight were used ($\underline{R}$ = .94). The investigators note that maximal oxygen consumption prediction ($ml \cdot kg^{-1} \cdot min^{-1}$) was $\underline{R}$ = .52 by simply using age, height, and weight.

Maximal effort running tests of varying distances have been used to estimate maximal oxygen consumption. Cooper (1968) developed a run/walk field test to estimate maximal oxygen consumption ($ml \cdot kg^{-1} \cdot min^{-1}$) based on the distance covered in 12 minutes. He found that for 115 men, ages 17 to 52 years, the correlation of the field test data with the laboratory oxygen consumption data was $\underline{r}$ = .90. Maksud and Coutts (1971) used Cooper's 12-minute run/walk test to study 80 boys, ages 11 to 14 years, and found that a 17 subject subset had a correlation coefficient between maximal oxygen consumption and run/walk performance of $\underline{r}$ = .65.

Doolittle and Bigbee (1968) studied 153 9th-grade boys to evaluate the 12-minute run/walk test and compared it with a 600-yard run/walk. Nine subjects performed a maximal oxygen consumption test. The correlation between maximal oxygen consumption ($ml \cdot kg^{-1} \cdot min^{-1}$) and the 12-minute run/walk was $\underline{r}$ = .90. The correlation between maximal oxygen consumption and the 600-yard run/walk was $\underline{r}$ = -.62. Test-retest reliability of the 12-minute run/walk was $\underline{r}$ = .94. Askew (1966) found the test-retest reliability of the 600-

yard run to range from $r = .65$ to $r = .92$ for various groups of junior and senior high school students.

Katch, McArdle, Czula, and Pechar (1973) also conducted a validation study of Cooper's 12-minute run/walk test. Using 36 college women, a correlation of $r = .67$ was obtained between the 12-minute run/walk test and maximal oxygen consumption ($ml \cdot kg^{-1} \cdot min^{-1}$). Getchell, Kirkendall, and Robbins (1977) studied adult women joggers and found that the correlation between direct measures of maximal oxygen consumption ($ml \cdot kg^{-1} \cdot min^{-1}$) and a 1.5-mile run time was $r = -.92$.

Sixty-nine young males, ages 9 to 12 years, were studied by Vodak and Wilmore (1975). It was found that the correlation between maximal oxygen consumption ($ml \cdot kg^{-1} \cdot min^{-1}$) and a 6-minute jog/walk was $r = .50$. It was also found that thee correlation between maximal oxygen consumption and a 600-yard run/walk was $r = -.50$. The validity coefficients indicated that these tests were poor predictors of maximal oxygen consumption for this group. Test-retest reliabilities were similar for the 6-minute jog/walk and the 600-yard run/walk ($r = .88$ and $r = .89$, respectively).

In studying various run tests in college males ($N = 44$), Burke (1976) found significant correlation coefficients between maximal oxygen consumption ($ml \cdot kg^{-1} \cdot min^{-1}$) and the 12-minute run ($r = .90$), the 600-yard run ($r = -.78$), the 1-mile run ($r = -.74$), and the 300-yard run ($r = -.52$).

Jackson and Coleman (1976) also found high correlation coefficients between maximal oxygen consumption ($ml \cdot kg^{-1} \cdot min^{-1}$) and runs of 3-, 6-, 9-, and 12-minute durations in upper elementary age children, with the 9- and 12-minute tests producing the best results ($\underline{r} = -.82$ for boys and $\underline{r} = -.71$ for girls for both the 9- and 12-minute runs). Analyzing lower elementary children, Krahenbuhl, Pangrazi, Petersen, Burkett, and Schneider (1978) found that the relationship of maximal oxygen consumption ($ml \cdot kg^{-1} \cdot min^{-1}$) with performance on timed runs of 800, 1200, and 1600 meters increased for the distance run for both males and females. The 1600-meter run time produced the only correlation coefficients better than $\underline{r} = -.60$. Krahenbuhl, Pangrazi, Burkett, Schneider, and Peterson (1977) found distance runs to be poor predictors of maximal oxygen consumption in 3rd-grade girls ($\underline{r} < .30$). Prediction in 3rd-grade boys, however, was above $\underline{r} = .70$ for the 1-mile run.

Ribisl and Kachadorian (1969) were able to use age, weight and runs of various distances to predict maximal oxygen consumption ($ml \cdot kg^{-1} \cdot min^{-1}$) in men. Multiple $\underline{R}$ values for young men and middle age men were .94 and .95, respectively.

Mayhew and Gifford (1975) evaluated 31 preadolescent boys for predicting maximal oxygen consumption using 21 anthropometric variables (skeletal dimensions, circumferences, skinfolds, and leg volume). A regression equation with a multiple R of .88 was developed to predict maximal oxygen consumption ($l \cdot min^{-1}$). However, the number of variables and the difficulty of measuring several variables, makes its use impractical in school settings.

Kline et al. (1987) utilized multiple regression analysis to estimate maximal oxygen consumption in adults (males = 165, females = 178). Predictor variables included elapsed time of a 1-mile track walk, gender, age, body weight, and heart rate. Comparing observed and estimated maximal oxygen consumption resulted in a multiple R of .92. The results indicate that this 1-mile walk test provides a valid submaximal assessment for maximal oxygen consumption estimation for adults ages 30 to 69 years. A popular walking test for adults was developed from results of this study (Rockport Walking Institute, 1988).

Dolgener, Hensley, Marsh, and Fjelstul (unpublished, 1990) conducted a study to validate the work of Kline et al. (1987) for college males and females and, if appropriate, develop new equations for this population. Subjects included 100 females and 96 females. The maximal oxygen consumption predicted from the Kline et al. (1987) study consistently overpredicted the measured maximal oxygen consumption by 23% in females and 16% in males. The correlations between measured maximal oxygen consumption ($l \cdot min^{-1}$) and the predicted value was $r = .58$ and $r = .48$ for males and females, respectively. The equation developed for this sample, using only sex and weight, produced a correlation of _R_ = .84. The sum of selected skinfold thicknesses was included as a variable in the development of a second generalized equation, along with sex, weight, and postwalk heart rate, and produced a correlation of _R_ = .86.

Mercier, Leger, and Lambert (1983) used a multistage 20-meter shuttle run test to develop maximal oxygen consumption predictions for children and youth ($ml \cdot kg^{-1} \cdot min^{-1}$). A modified version of a test developed and used for adults by Leger and Lambert (1982) was used. The speed was set by a prerecorded cassette. It was increased from 8.5 kilometers per hour, at a rate of 0.5 kilometers per hour each successive minute, until the subjects could no longer maintain the pace. Subjects included 200 males and females, ages 8 to 19 years. Maximal speed, age, and sex were used as predictor variables. The multiple correlation coefficient of predicted and direct measures was _R_ = .86. Leger and Gadoury (1989) validated this test with adults (53 males and 24 females, ages 19 to 47 years) and found correlations of _R_ = .90. It was concluded that the 20-meter shuttle run is a valid test to predict maximal oxygen consumption in children and adults.

Summary of Cardiorespiratory Field Tests

There have been numerous field tests reported in the literature to predict maximal oxygen consumption. A variety of testing protocols have been employed (see Table 1).

Table 1

Summary of VO_{2max} Prediction Tests

Study	N	Age	Sex	Predictor Variables	R or r
			Bench Step Test		
McArdle (1972)	41	18-22	F	Recovery HR	.75[a]
			Cycle Ergometer Tests		
Astrand & Ryhming (1954)	27	18-30	M	HR at 900/1200 kpm	-
	31		F	HR at 600/900 kpm	-
Fox (1973)	87	17-27	M	5th min HR at 900 kpm	.76[a]
Mastrapaolo (1970)	13	43-61	M	RER, DBP, VE, FeO_2, Work (kpm)	.93[a]
Siconolfi et al. (1982)	63	20-70	M/F	Age, VO_2 predicted from Astrand-Rhyming	.94[a]
	25		M		.86[a]
	28		F		.97[a]
Knuttgen (1967)	95	15-18	M	WT, PWC 170	.71[a]
	95	15-18	F	WT, PWC 170	.86[a]
Bonen et al. (1979)	100	7-15	M	HR, VCO_2, VO_2 HT,	.95[a]
				Age, WT, HT	.52[b]

(table continues)

Study	*N*	Age	Sex	Predictor Variables	*R* or *r*
			Treadmill Tests		
Metz & Alexander (1971)	60	12-13	M	HR, VO_2, RER	.70[a]
		14-15	M		.48[a]
Herminston & Faulkner (1971)	28	25-45	M	Age, FFW, HR, $FeCO_2$, V_T, RER	.90[a]
					.90[a]
			Run and/or Walk Tests		
Cooper (1968)	115	17-52	M	12-min run/walk distance	.90[b]
Doolittle & Bigbee (1968)	9	14-15	M	12-min run/walk distance	.90[b]
	9	14-15	M	600-yard run/walk time	.62[b]
Getchell et al. (1977)	21	18-25	F	1.5-mile run/walk time	.46[a]
					.91[b]
Burke (1976)	44	college	F	12-min run/walk distance	.90[b]
				600-yard run/walk time	-.78[b]
				1-mile run/walk time	-.74[b]
				300-yard run time	-.52[b]
Krahenbuhl (1977)	22	3rd grade	M	600-yard run/walk time	-.58[b]
				3/4-mile run/walk time	-.64[b]
				1-mile run/walk time	-.71[b]
	22	3rd grade	F	600-yard run/walk time	.03[b]
				3/4-mile run/walk time	-.22[b]
				1-mile run/walk time	-.26[b]

(table continues)

Study	N	Age	Sex	Predictor Variables	R or r
Vodak & Wilmore (1975)	69	9-12	M	6-min run/walk distance	.50[b]
				600-yard run/walk time	-.50[b]
Jackson & Coleman (1976)	22	upper el	M	9-min run/walk distance	.82[b]
				12-min run/walk distance	.82[b]
	25	upper el	F	9-min run/walk distance	.71[b]
				12-min run/walk distance	.71[b]
Krahenbuhl et al. (1978)	49	lower el	M	800-meter run/walk time	-.22[b]
				1200-meter run/walk time	-.47[b]
				1600-meter run/walk time	-.60[b]
	34	lower el	F	800-meter run/walk time	-.49[b]
				1200-meter run/walk time	-.43[b]
				1600-meter run/walk time	-.74[b]
Ribisl & Kachadorian (1969)	24	30-48	M	Age, WT, 100-yard run time	.95[b]
	11	18-22	M	200 yard run time, 2-mile run/walk time	.94[b]
Maksud & Coutts (1971)	17	11-14	M	12-min run/walk distance	.65[b]
Metz & Alexander (1970)	30	12-13	M	600-yard run/walk time	-.67[b]
	30	14-15	M	600-yard run/walk time	-.27[b]
Mercier et al. (1983)	200	8-19	M F	Multistage 20-meter shuttle run, Age, Sex	.86[b]
Leger & Gadoury (1989)	77	19-47	M F	Multistage 20-meter shuttle run, Age, Sex	.90[b]

(table continues)

Study	N	Age	Sex	Predictor Variables	R or r
Kline et al. (1987)	343	30-69	M/F	1-mile walk time, Age, Postwalk HR, WT	.93[a]
Dolgener et al. (1990)	196	college	M/F	Postwalk HR, WT, Sum of skinfolds, Sex	.86[a]
				Other Tests	
Jessup et al. (1974)	40	18-23	M	DBP, Leg length, 12-min run/walk distance, $\dot{V}O_2$ predicted from Astrand-Rhyming	.81[a] .69[b]
Falls et al. (1966)	87	23-58	M	AAHPERD Fitness Test: pull-ups, 50-yard dash time, shuttle run time, 600-yard run time	.54[a] .76[b]
Metz & Alexander (1970)	30 30	12-13 14-15	M M	AAHPER Fitness Test, McCloy Strength Test, Harvard Step Test	.78[b] .68[b]
Buskirk & Taylor (1975)	31	pre-pubescent	M	Skeletal dimensions, Circumferences, Skinfolds	.88[a]

<u>Note</u>. [a]Correlated with direct measure of maximal oxygen consumption expressed in $l \cdot min^{-1}$.

[b]Correlated with direct measure of maximal oxygen consumption expressed in $ml \cdot kg^{-1} \cdot min^{-1}$.

Abbreviations used are: VO_2 = oxygen consumption; FFW = fat-free weight, VE = minute ventilation; V_T = tidal volume; DBP = diastolic blood pressure; RER = respiratory exchange ratio; $FeCO_2$ = fractional concentration of carbon dioxide in expired gas; FeO_2 = fractional concentration of oxygen in expired gas; WT = weight; HT = height; HR = heart rate (beats per minute); kpm = kilopond meters per minute; PWC 170 = physical work capacity evaluated from work load data at a heart rate of 170 b/min; el = elementary.

Prediction of maximal oxygen consumption in children and youth based on formulas that use submaximal heart rates and other variables derived for adults have the potential of producing large errors (Bar-Or, Shephard, & Allen, 1971; Cunningham & Eynon, 1973; Davies, 1968; Rowell, Taylor, & Wang, 1964). The disadvantages of using bench stepping, cycle ergometry, and treadmill testing in school populations has previously been addressed in Chapter I. Maximal effort running tests demand considerable subject cooperation, which has presented problems in testing children and youth (Cunningham, Telford, & Swarth, 1976; Metz & Alexander, 1970).

Mercier et al. (1983) successfully developed an indoor field test for the prediction of maximal oxygen consumption, in children and youth. A multistage 20-meter shuttle run test and other simple variables were used in the prediction. Bonen, et al. (1979) was able to accurately predict maximal oxygen consumption in boys, using a submaximal treadmill walk and other parameters. Simple physical measurements also provided reasonably accurate maximal oxygen consumption predictions for this group. Mayhew and Gifford (1975) successfully used anthropometric measures to predict maximal oxygen consumption in boys. Recently, multiple linear regression predictions based on walking and other field measurements have been developed to predict maximal oxygen consumption in adult and college populations (Kline et al., 1987; Dolgener et al., 1990). These procedures appear to provide good predictive accuracy due to the statistical combination of factors accounting for the variation associated with maximal oxygen consumption.

Implications in School Settings

Ross and Gilbert (1985) reported that 80% of students in Grades 5 through 12, in the United States, were enrolled in physical education classes. The average weekly number of class meetings was 3.6. Later, they reported that 97% of primary students were enrolled in physical education classes, with the average weekly number of class meetings being 3.1. Approximately one-half of these children participated in physical fitness testing programs (Ross & Gilbert, 1987). The potential for impacting the physical fitness levels of large numbers of school aged children and youth is evident.

Several physical fitness testing programs, which include award components, enjoy widespread use in schools. In a letter to Iowa school superintendents, four such programs were recommended for use by the Chairperson of the Iowa Governor's Council on Physical Fitness and Sports (R. DeAnda, personal communication, September 6, 1990). Included were: (a) Physical Best, sponsored by the American Alliance for Health, Physical Education, Recreation and Dance (McSwegin, Pemberton, Petray, & Going, 1989), (b) Fitnessgram, sponsored by the Institute for Aerobics

Research and Campbell's Institute for Health and Fitness (Institute for Aerobics Research, 1987), (c) President's Challenge Program, sponsored by the President's Council on Physical Fitness and Sports (U.S. Department of Health and Human Services, 1988), and (d) Chrysler Fund/AAU Test, sponsored by the Chrysler Corporation and the Amateur Athletic Union (Amateur Athletic Union, 1988). All of these test batteries include a 1-mile run/walk test as a measure of cardiorespiratory fitness. (The Chrysler Fund/AAU Test also uses shorter distances for children under 12 years of age.)

As a method of adjusting for body size, studies evaluating the validity of distance running tests have generally used maximal oxygen consumption expressed in $ml \cdot kg^{-1} \cdot min^{-1}$ to measure cardiorespiratory fitness. Buskirk and Taylor (1957) and Welch, Reindeau, Crisp, and Isenstein (1958), in early work, suggested that when maximal oxygen consumption is used to examine the capacity to perform exhaustive work, the values should be expressed in $ml \cdot kg^{-1} \cdot min^{-1}$. In studies of 20 or more children or youth, relationships between distance runs of one mile or more and maximal oxygen consumption ($ml \cdot kg^{-1} \cdot min^{-1}$) generally produce correlation coefficients in the range of $\underline{r} = .50$ to $\underline{r} = .80$ (Cureton, Boileau, Lohman, & Misner, 1977; Jackson & Coleman, 1976; Krahenbuhl, Pangrazi, Petersen, Burkett, & Schneider, 1978; Vodak & Wilmore, 1975).

As noted by Cureton (1982), critics of using distance running performance for evaluation of cardiorespiratory fitness in children and youth cite running skill, pacing, motivation, and body composition as being compounding factors. However, the value of distance running tests are defended for their reflection of physical work capacity in weight-bearing exercise or the ability to sustain prolonged high energy expenditure.

The use of distance running performance has appeal from a test administration standpoint and for its ease of normative development for school populations. However, it appears that a relatively small portion of variance on distance running performance alone reflects variance on maximal oxygen consumption for children and youth.

Use of Pulse for Heart Rate Monitoring

Heart rate has long been used to estimate exercise intensity. In field settings, determining heart rate via postexercise pulse palpitation has been the most frequently used method.

Cotton and Dill (1935) studied 12 middle-aged men and found that during the first 10 seconds following strenuous exercise, heart rate decreased on an average just one beat per minute. Pollock, Broida, and Kendrick (1972) found that heart rates decreased less than 2% within 12 to 14 seconds after exercise in 37 middle-aged men. This was measured during palpation of the postexercise carotid or apical pulse.

McArdle, Zwiren, and Magel (1969) found that the error in estimating the exercise heart rate of 10 young men from telemetry readings taken during the 10 seconds immediately following strenuous exercise, of approximately 180 beats per minute, averaged 2.7%. This increased to 7.6% during the first 10 seconds of recovery from rates of approximately 140 beats per minute. By use of a 30 second recovery interval, it was possible to underestimate the strenuous exercise heart rate by 9 to 22 beats per minute. It was also found that the rate of recovery was not similar for all individuals.

Concerned about the implications of the carotid sinus reflex and heart rate changes, investigators have specifically studied postexercise carotid artery palpation. White (1977) found significant heart rate lowering while studying postexercise carotid artery palpation in 78 men and 39 women. Gardner, Danks, and Scharfsiein in (1979) were unable to confirm these findings in a similar population. Oldridge, Haskell, and Single (1981) studied the effect of postexercise carotid artery palpation in 60 men with coronary heart disease and concluded that this method was an accurate indicator of the exercise heart rate and did not result in spuriously low postexercise heart rates. Boone, Frentz, and Boyd (1985) found a significant decrease in heart rate during postexercise carotid artery palpation in 21 healthy young women (6.1 and 3.3 beats per minute at two exercise intensities).

The accuracy of pulse counting by adults has been investigated. Slater-Hammel and Butler (1940) studied the accuracy of securing pulse rates by palpation of the radial pulse. Pulse rates were taken from subjects before and after exercise by resident physicians and university physical education faculty. A comparison of rates obtained by palpation and simultaneous plethsymograph recordings indicated considerable error (a range of -12 to +4 beats per minute at rest and a range of -33 to +36 beats in two minutes of postexercise counting). The authors suggested a need for accurate mechanical methods for taking pulse counts in physical education testing programs.

Pollock et al. (1972) studied the accuracy of self-pulse counting by palpation of the carotid and apical pulse in 37 middle-aged men. Heart rates were counted following running and were also monitored via telemetry. Postexercise values via telemetry and postexercise subject count (170.1 vs. 169.4 beats per minute) showed a 1% difference. It was concluded that training rates can be estimated during exercise recovery (beats per 10 seconds) and that the palpation technique for estimating heart rate can be adequately determined by adult men while training.

Couldry, Corbin, and Wilcox (1982) compared carotid, radial, and electrocardiogram pulse rates in 20 middle-aged men and women. The investigators found that resting and postexercise counts using palpation of either the carotid or radial pulses were not significantly different from those taken by electrocardiogram tracings. Also, resting and postexercise heart rates taken by radial and carotid artery palpations did not differ. Counts done after exercise by either method were also not different from exercise heart rate by electrocardiograms. Sedlock, Knowlton, Fitzgerald, Tahamont, and Schneider (1983) also investigated postexercise heart rate comparisons determined by carotid artery palpation, radial artery palpation, and simultaneous electrocardiogram. There were no significant differences between heart rates counted by subjects (84 college students) and those recorded by electrocardiogram using either method.

Little is known about the ability of children and youth to monitor their own elevated heart rates via self-pulse counting. Best and Steinhardt (1990) investigated the ability of third (N = 45), fourth (N = 44), and fifth (N = 44) grade children to accurately count and report their heart rate during the fitness development phase of physical education class. Subjects initially participated in a training session in which they were instructed in and practiced carotid artery palpation. Heartwatch values were compared to each child's reported values of 5 and 10 second pulse counts. (Heartwatch values were generally less than 60% of the subjects' predicted maximum heart rate reserve.) Results of a 3 x 3 x 2 (Grade x School x Method) repeated measures ANOVA found significant Grade x School x Method interactions. Children in Grade 5 could accurately count their postexercise pulse ($p < .01$), whereas children in Grade 3 and Grade 4 could not.

CHAPTER III

METHODOLOGY

This study investigated the use of a shuttle walk protocol, in combination with other selected field measurements, for predicting maximal oxygen consumption in boys, ages 11 to 14 years. Specifically, the following predictor variables were considered in the development of the prediction equations: (a) elapsed time on an 800-yard shuttle walk, (b) telemetrically measured postexercise heart rate (following a shuttle walk test), (c) height, (d) weight, (e) sum of triceps and subscapular skinfold thicknesses, (f) body mass index, and (g) days per week of physical activity that elicits sweating and hard breathing for 20 minutes or more. The difference between postexercise heart rate, as measured by self-pulse counting and telemetry, was also investigated.

Subjects

Subjects for this study included 69 apparently healthy boys, ages 11 to 14 years, from Cedar Falls, Waterloo, and the surrounding area. This convenience sample was recruited via a letter to the potential subjects' parents (see Appendix A). All subjects were volunteers. Of the original 69 subjects, 67 subjects were included in the final analysis, with two subjects eliminated due to equipment failure which occurred during treadmill testing. A parent, or legal guardian, of each subject completed a physical activity readiness questionnaire designed to screen for cardiovascular and orthopedic contraindications to exercise testing (see Appendix B). An informed consent document was signed by each participant and a parent, or legal guardian (see Appendix C). Each subject's blood pressure was measured to screen for hypertension prior to testing, however, none was found. The sample included 27 boys from Waterloo (of which 24 boys attended Logan Intermediate School), 25 boys from Cedar Falls, and 15 boys from surrounding areas. Included were 54 whites, 9 blacks, 2 mixed race, 1 Hispanic, and 1 Asian.

Procedures

Permission was sought and granted by the administration of Allen Memorial Hospital in Waterloo, Iowa for the study to be conducted at that site. Permission was also sought and granted by the Institutional Review Board of the University of Northern Iowa. Additionally, permission was sought and granted by the central administration of the Waterloo Community School District and the principal at Logan Intermediate School to recruit and test Logan Intermediate School students during regularly scheduled instructional time.

Data Collection

Testing was conducted at Allen Memorial Hospital from May 19 through July 30, 1990. A gymnasium was used to conduct the walking tests and two other areas in the hospital were used to conduct the treadmill tests. All areas were climate controlled.

All data were collected by or under the supervision of the principal investigator. Data collection assistance was provided by two University of Northern Iowa practicum students. Technical and data collection assistance was also provided by the Director of Cardiopulmonary Services at Allen Memorial Hospital.

Subjects arrived for testing either individually or in small groups. All phases of the testing were scheduled for completion in one session. Subjects refrained from eating at least one hour prior to exercise testing.

Height. Subjects were measured while barefoot or wearing socks. They stood with heels, scapulae, buttocks, and the posterior aspect of the cranium in contact with a door. Heels were touching each other. If a subject had knock knees, the feet were separated and the medial borders of the knees were touched. The head was positioned in the Frankfort Horizontal Plane, as described by Lohman, Roche, and Martorell (1988). That is, the left tragion and most inferior point of the left orbital margin were at the same horizontal level. (Tragion is the point in the notch above the tragus of the auricle.) A headboard (constructed at a 90 degree angle) was placed against the door and onto the highest point of the head. The measurement was recorded to the nearest one-fourth inch. Metric conversions were derived by multiplying height in inches by 0.0254 and truncating to two decimal places in order to obtain values in meters.

Weight. Subjects were weighed in undershorts using a Healthometer balance type scale (Continental Scale Corporation, Bridgeview, IL). The scale was calibrated with known weights prior to the data collection period. The measurement was recorded to the nearest one-fourth pound. Metric conversions were derived by dividing weight in pounds by 2.2 and truncating to one decimal place in order to obtain values in kilograms.

Body mass index. The converted metric values of height and weight were used to compute body mass index. Weight in kilograms was divided by the height^2 in meters and truncated to one decimal place.

Subscapular and triceps skinfold thicknesses. As described by Harrison et. al. (1988), the site of the subscapular skinfold was marked on a diagonal, inclined infero-laterally approximately 45 degrees to the horizontal plane in the natural cleavage of the skin on the right side. The site of the triceps skinfold was marked on the midline of the posterior aspect of the right arm, over the triceps muscle. This was situated midway between the lateral projection of the acromion process of the scapula and the inferior margin of the olecranon process of the ulna. This distance was measured with a cloth measuring tape on the lateral side of the right arm with the elbow flexed at 90 degrees. The triceps skinfold was taken as a vertical fold with the arms relaxed at the side.

Skinfold thickness measurements were made using a Lange skinfold caliper (Cambridge Scientific Industries, Inc., Cambridge, MD). The general technique employed was that of picking up a skinfold with the thumb and index finger approximately one centimeter above the measurement site. The jaws of the caliper were positioned so that the skinfold thicknesses were measured perpendicular to the long axis of the skinfold, at the marked site. The release of pressure was gradual and the measurement was made approximately four seconds after the release. The skinfold was kept elevated until the measurement was completed. Three skinfold thicknesses were measured at both the subscapular and triceps sites. Measurements were recorded to the nearest millimeter. Subscapular and triceps measurements were separately averaged and rounded to two decimal places. These two averaged values of subscapular and triceps skinfold thicknesses were summed in order to generate the sum of skinfold thicknesses.

Days per week of physical activity. On the day of testing, subjects were verbally asked the following question, "Considering the past month, how many days a week did you typically get physical activity that made you sweat and breathe hard for 20 minutes or more?" Response choices were zero, one, two, three, four, five, six, or seven.

Self-pulse counting. Subjects were instructed in the techniques of self-pulse counting of the carotid artery and were given the opportunity to practice counting their own carotid artery pulse prior to participating in the shuttle walk test. Subjects counted their own pulse following the timed walk.

The technique for self-pulse counting employed the palpation of the carotid artery and the counting of the pulse for 15 seconds. This was done with the aid of a pace clock with a sweep second hand. In order to coordinate the pulse counting, each subject was instructed to answer "yes" or "no" when an investigator asked if he was "ready" to count. If the response was "yes," the investigator used the command "count" when the second hand of the clock fell on a mark that represented a multiple of five. (Subjects were to begin their count with the number one.) If the response was "no," the investigator repeated the "ready" query a second and third time, if needed. If a subject was unable to find his own pulse after the third query, it was noted as such on the data collection sheet and no self-reported pulse count was recorded. However, all subjects indicated that they were able to find their own pulse on or before the third query. When the second hand fell on the mark which was 15 seconds after the start, the investigator used the command "stop" to designate the termination of pulse counting.

Shuttle walk. Two electrodes were positioned on each subject in order to approximate a lead II axis for electrocardiogram recording. A Gemini Twin Telemetry System (Marquette Electronics Inc., Milwaukee, WI) was used for this purpose. This equipment was regularly inspected in accordance with hospital maintenance schedules (inspected May, 1990).

Subjects were instructed to walk 800 yards as fast as possible on a 20-yard shuttle course. This was the length of a standard sized volleyball court. No two subjects started the walk simultaneously. When turning, one foot was required to touch or cross the end line. Laps were counted and subjects were informed of the remaining number of laps to complete. The walk was timed, to the nearest second, with a digital stop watch.

Immediately following the walk, subjects counted their own pulse for 15 seconds, as previously described. An electrocardiogram was recorded via telemetry during the pulse counting period. To ensure that the time interval of self-pulse counting could be captured on the electrocardiogram, the recorder was turned on prior to the start of self-pulse counting. The electrocardiogram paper was then marked adjacent to the stylus at the time the beginning and ending commands for self-pulse counting were given. Commands were given by the investigator and the stylus was marked by an assistant.

The number of heart beats in the 15 second interval was determined by counting the number of QRS complexes between the beginning and ending marks. If the peak of QRS complex fell on a mark, it was not counted. Heart rate was recorded in beats per minute by multiplying the number of heartbeats measured in 15 seconds by 4.

Treadmill testing. Measurement of maximal oxygen consumption followed the shuttle walk test. Prior to treadmill testing, subjects practiced walking and running on a motorized treadmill and were instructed on testing procedures. Included were instructions on communication signals which were used while wearing the gas collection apparatus, focusing particularly on test termination. Subjects were encouraged during preliminary instructions and throughout the treadmill testing to continue until they had given their best effort. Subjects were observed during testing for signs of fatigue by the principal investigator.

Both a Quinton Model Q55 treadmill (Quinton Instruments Co., Seattle, WA) and a Trackmaster Model TM2 treadmill (Jas Fitness Systems, Pensacola, FL) were used for testing. The treadmill protocols used for this study were modified versions of one used by Vodak and Wilmore (1975). Treadmill speed was set at 3.0 miles per hour for the first 3 minutes. Elevation started at 0% grade for the first minute and was increased the second and third minute by 2.5% grade. The speed was increased to 5.0 miles per hour at the beginning of the fourth minute with the elevation remaining at 5.0% grade during the fourth minute. The speed remained at 5.0 miles per hour with the elevation increased by 2.5% each subsequent minute until the maximum treadmill grade was achieved. For each additional minute, the speed was then increased by 1.0 mile per hour, with the elevation remaining constant.

Testing protocols at higher workloads were not identical. Testing initially began using the Quinton Model Q55 treadmill, which had a higher elevation capacity than the Trackmaster Model TM2 treadmill (25% grade versus 20% grade). Later in the testing schedule, it was determined that a second testing area equipped with a Trackmaster TM2 treadmill would be utilized. This was necessitated because the testing schedule coincided with the relocation of the stress testing laboratory and also because of improved logistics. Six of the 19 subjects who achieved workloads higher than 5.0 miles per hour at 20% grade (the workload up to which both treadmill protocols were identical) were tested on the Quinton Model Q55 treadmill.

Peak oxygen consumption was determined for each subject and used as the criterion measure for maximal oxygen consumption in developing the prediction equations. Peak oxygen consumption values were determined by the collection and analysis of expired gases using a SensorMedics Horizon TM System (SensorMedics Corporation, Anaheim, CA). This equipment was regularly inspected in accordance with hospital maintenance schedules (inspected May, 1990). Gas calibrations were completed prior to each testing session. Gas analysis occurred every 15 seconds throughout the treadmill testing. Peak oxygen consumption was taken to be the highest value achieved prior to or at the time when the treadmill test was discontinued and the workload was decreased.

Peak oxygen consumption may not represent true physiological maximal oxygen consumption since other criteria were not used to establish a true maximal oxygen consumption (i.e. a leveling off of oxygen consumption despite an increase in work). However, for oxygen consumption tests of children and youth requiring volitional exhaustive effort, peak values have been commonly used to represent maximal oxygen consumption (Bonen et al., 1979; Cunningham & Eyon, 1973; Doolittle & Bigbee, 1968; Krahenbuhl et al., 1978; Vodak & Wilmore, 1975). Bonen et al. (1979) established the reliability of a peak oxygen consumption measurement in 7- to 15-year-old boys by retesting 21 of 100 subjects and found test-retest reliability coefficients of $\underline{r}$ = .97 and $\underline{r}$ = .87 for maximal oxygen consumption expressed in $l \cdot min^{-1}$ and $ml \cdot kg^{-1} \cdot min^{-1}$, respectively.

Absolute maximal oxygen consumption values were reported in $l \cdot min^{-1}$. Relative maximal oxygen consumption values, reported in $ml \cdot kg^{-1} \cdot min^{-1}$, were computed by expressing absolute values in $ml \cdot min^{-1}$ and dividing by body weight in kilograms.

Maximal heart rate. Electrocardiograms were obtained at the time the subjects achieved volitional fatigue during the treadmill test via telemetry, as previously described. Maximal heart rates were determined by measuring the distance between the first six clearly identifiable QRS complexes and were reported in beats per minute.

Data Analysis

Descriptive characteristics for the volunteer sample of 67 boys are presented in the next chapter. The data were used to develop equations for predicting absolute ($l \cdot min^{-1}$) and relative ($ml \cdot kg^{-1} \cdot min^{-1}$) peak oxygen consumption. Stepwise multiple linear regression analysis was used. The prediction variables included: (a) elapsed time of a shuttle walk, (b) telemetrically measured post exercise heart rate (following a shuttle walk test), (c) height, (d) weight, (e) sum of triceps and subscapular skinfold thicknesses, (f) body mass index, and (g) days per week of physical activity that elicits sweating and hard breathing for 20 minutes or more. Multiple correlation coefficients and standard error of the estimates are reported for the prediction equations. A correlation matrix for the predictor variables is also presented in the next chapter.

Acceptance of hypothesis 1 was based on identifying a maximal oxygen consumption prediction equation, expressed in either $l \cdot min^{-1}$ or $ml \cdot kg^{-1} \cdot min^{-1}$, with an R^2 value $\geq .50$. This criteria for acceptability has previously been used by several investigators in maximal oxygen prediction studies (Issekutz, Birkhead, & Rodahl, 1962; Metz & Alexander, 1971; Teraslinna et al., 1966) and assures that a minimum of 50% of the maximal oxygen consumption variance is accounted for.

The relationship between heart rate, as measured by self-pulse counting and telemetry, was also investigated. A paired t test was used to test hypothesis 2. The statistical significance level was set at .05. A Pearson's product-moment coefficient of correlation was also used to further examine the relationship.

CHAPTER IV

RESULTS AND DISCUSSION

This study investigated the use of a shuttle walk protocol, in combination with other selected field measurements, for predicting maximal oxygen consumption in boys, ages 11 to 14 years. Specifically, the following predictor variables were considered in the development of the prediction equations: (a) elapsed time on an 800-yard shuttle walk, (b) telemetrically measured postexercise heart rate (following the shuttle walk test), (c) height, (d) weight, (e) sum of triceps and subscapular skinfold thicknesses, (f) body mass index, and (d) days per week of physical activity that elicits sweating and hard breathing for 20 minutes or more. The difference between postexercise heart rate, as measured by self-pulse counting and telemetry, was also investigated.

This chapter is comprised of three major sections. The first section provides descriptive statistics for the variables. The second section contains data and discussion related to the first hypothesis, in which the prediction of maximal oxygen consumption from the specified variables is addressed. The third section contains data and discussion related to the second hypothesis, in which the accuracy of self-pulse counting by boys is addressed.

Descriptive Statistics

The means and standard deviations for physical characteristics, exercise frequency, submaximal shuttle walk measurements, and maximal treadmill protocol parameters are shown in Table 2.

Table 2

Physical Characteristics of the Subjects and Responses to the Shuttle Walk and $\dot{V}O_{2Max}$ Tests

Parameter	N	M	SD
Physical			
Age (years)	67	12.8	1.0
Height (inches)	67	62.2	4.4
Weight (pounds)	67	110.7	29.2
Skinfold sum (mm)	67	22.9	15.1
Body mass index	67	19.9	3.7
Exercise frequency and submaximal work			
Exercise frequency (days/week)	67	4.4	1.6
Walk time (seconds)	67	357.1	39.5
Postwalk HR via telemetry (b/min)	67	165.1	22.0
Maximal work			
Heart rate (b/min)	63	202.7	8.9
Respiratory exchange ratio	67	1.13	0.07
$\dot{V}O_{2max}$ ($l \cdot min^{-1}$)	67	2.58	0.62
$\dot{V}O_{2max}$ ($ml \cdot kg^{-1} \cdot min^{-1}$)	67	52.3	8.4

Mean maximal oxygen consumption values ($ml \cdot kg^{-1} \cdot min^{-1}$), reported by other investigators, ranged from 44.5 to 56.6 for boys of similar age (Bar-Or, Shephard, & Allen, 1971; Bonen et al., 1979; Cunningham & Eynon, 1973; Cunningham et al., 1976; Jackson & Coleman, 1976; Maksud & Coutts, 1971; Metz & Alexander, 1971; Vodak & Wilmore, 1975). The mean maximal oxygen consumption value of 52.3 $ml \cdot kg^{-1} \cdot min^{-1}$ in this investigation was higher than mean values reported by Bar-Or et al. (1971), Bonen et al. (1979), Jackson and Coleman (1976), and Maksud and Coutts (1971), but was lower than values reported by Cunningham et al. (1976), and Vodak and Wilmore (1975). Cunningham and Eynon (1973), and Metz and Alexander (1971) reported maximal oxygen consumption values that were both higher and lower than the present study for various sub-groups of boys.

The mean maximal heart rate of 202.7 beats per minute, measured during the treadmill test was higher than mean maximal heart rates reported for boys of similar or younger ages by other investigators, which have ranged from 190.6 to 200.6 beats per minute (Krahenbuhl et al., 1977; Krahenbuhl et al., 1978; Maksud & Coutts, 1971; Metz & Alexander, 1971). Of the 63 subjects from which maximal heart rate values were garnered, all heart rates were above 180 beats per minute. It was the investigator's subjective observation that the overall effort of the subjects during treadmill testing was good. Analysis of the respiratory exchange ratio supports this observation. The mean respiratory exchange ratio of 1.13 at maximal effort was comparable to or somewhat higher than values reported by other investigators. Krahenbuhl et al. (1977), Krahenbuhl et al. (1978), and Metz and Alexander (1971) reported mean values of 1.13, 1.06, and 1.10, respectively. Only 2 of the 67 subjects in this study failed to achieve a respiratory exchange ratio of 1.00, the lowest being .98. The higher mean maximal heart rate may be attributed to the good overall effort put forth by the subjects during treadmill testing.

The postwalk heart rate mean was 165.1 beats per minute, with a standard deviation of 22.0 beats per minute. Percent of maximal heart rate was calculated by dividing postwalk heart rate by maximal heart rate achieved during treadmill testing. The mean percent of maximal heart rate was 81.5%, with a standard deviation of 10.3%. The 70% and 80% of maximal heart rate levels were achieved by approximately 88% and 56% of the boys, respectively, during the shuttle walk. These results suggest that fast walking is an appropriate cardiorespiratory fitness activity for many boys, ages 11 to 14 years.

The sum of triceps and subscapular skinfold measurements for boys in this study at the 25th, 50th, and 75th percentile ranks were comparable to the sum of triceps and subscapular skinfold measurements reported for boys of comparable ages at the 25th, 50th and 75th percentiles in the National Children and Youth Fitness Study (NCYFS) (Ross, Dotson, Gilbert, & Katz, 1985). In the present study, the 25th, 50th, and 75th percentile ranks had sum of skinfold measurements of 25, 17, and 14 mm, respectively. All of these values were within the ranges reported for boys, ages 11 to 14 years, in the National Children and Youth Fitness Study. The mean sum of triceps and subscapular skinfold measurements was 22.8 mm. This was slightly higher than mean values reported in the NCYFS for boys 11-, 12-, 13-, and 14-years of age, which ranged from 20.1 to 21.6 mm. Skinfold measurements from the sample in this study were positively skewed, which may be the reason for a somewhat higher mean value than that reported in the NCYFS. However, the sample in this study was somewhat representative of a larger national sample. Data for the NCYFS were collected from a random sample of 8,800 boys and girls from 140 public and private schools in 19 states.

To explore the value of repeating skinfold measurements, intrameasurer reliability was established for both the triceps and subscapular skinfold measurements by measuring each site three times and using these measurements to establish reliability coefficients. Alpha coefficients were greater than $\underline{r} = .99$ for both the triceps and subscapular skinfold measurements. Ross, Katz, and Gilbert (1985) reported an intermeasurer reliability coefficient of

.94 while field measuring triceps and subscapular skinfolds for analysis in the NCYFS. (Lange skinfold calipers were used in both the NCYFS and the present study.) Other investigators have also found the reproducibility of triceps and subscapular skinfold measurements, in children and youth, to be good for both intrameasurer and intermeasurer values. Studies by Johnston, Hamill, and Lemeshow (1972, 1974) reported errors to be less than two mm (cited in Harrison et al., 1988). In school settings, it may suffice for an experienced measurer to measure each site only once. A practical suggestion is to compare skinfold measurements between measurers.

Eighty-eight percent of the subjects indicated that during the month previous to the study, they participated in exercise which made them sweat and breathe hard for 20 minutes or more, three or more days a week. Ross and Gilbert (1985) reported that only 45% of 5th- through 12th-grade boys regularly participated in at least this much cardiorespiratory activity. A possible reason for this discrepancy may have been due to the fact that data for the present study were collected during the late spring and summer months when boys were typically engaged in more outdoor activity. Also, boys who volunteer for a study of this nature may be more likely to participate in vigorous physical activity than their counterparts. Exercise frequency was positively correlated with maximal oxygen consumption, expressed in $ml \cdot kg^{-1} \cdot min^{-1}$, in this study ($\underline{r}$ = .24, $\underline{p}$ < .05).

Hypothesis 1

It was hypothesized that a linear combination of predictor variables including: (a) elapsed time on a shuttle walk of 800 yards, (b) telemetrically measured postexercise heart rate (following a shuttle walk test), (c) height, (d) weight, (e) sum of triceps and subscapular skinfold thicknesses, (f) body mass index, and (g) days per week of physical activity that elicits sweating and hard breathing for 20 minutes or more could be identified which will accurately predict maximal oxygen consumption in 11- to 14-year-old boys. The correlation matrix of the predictor variables and dependent variables is shown in Table 3.

Retaining all predictor variables, the highest prediction of maximal oxygen consumption, expressed in $l \cdot min^{-1}$, resulted in a multiple $\underline{R}$ of .90, with a SEE of 0.287 $l \cdot min^{-1}$ (see Table 4). Retaining all predictor variables, the highest prediction of maximal oxygen consumption, expressed in $ml \cdot kg^{-1} \cdot min^{-1}$, resulted in a multiple $\underline{R}$ of .84, with a SEE of 4.7 $ml \cdot kg^{-1} \cdot min^{-1}$ (see Table 4). However, removing predictor variables that did not provide a significant and unique contribution allowed the prediction to be less cumbersome. The data were entered in a stepwise multiple linear regression procedure, using a backward solution (Statistical Package for Social Science)

Table 3

Intercorrelations of Independent and Dependent Variables

	1	2	3	4	5	6	7	8
1. Height (inches)								
2. Weight (pounds)	.73							
3. Skinfold sum (mm)	.08	.64						
4. Body mass index	.32	.87	.85					
5. Exercise frequency (days/week)	-.19	-.20	-.11	-.17				
6. Walk time (seconds)	-.15	.17	.43	.36	-.25			
7. Postwalk HR (b/min)	-.02	-.05	-.11	-.07	.05	-.61		
8. $\dot{V}O_{2max}$ ($l \cdot min^{-1}$)	.84	.67	-.01	.34	-.09	-.13	-.09	
9. $\dot{V}O_{2max}$ ($ml \cdot kg^{-1} \cdot min^{-1}$)	.00	-.51	-.80	-.73	.24	-.42	.00	.27

Note. N = 67.

[a] *r* = .24 significant at the .05 level.

[b] *r* = .31 significant at the .01 level.

to select appropriate variables to retain for the prediction of maximal oxygen consumption, expressed in $l \cdot min^{-1}$ and $ml \cdot kg^{-1} \cdot min^{-1}$.

Further stepwise multiple linear regression procedures were used to determine if equations could be developed with fewer variables and yet retain relatively good predictive accuracy. Prediction equations are shown in Table 5 ($l \cdot min^{-1}$) and Table 6 ($ml \cdot kg^{-1} \cdot min^{-1}$), which include only predictor variables that significantly influence the prediction

Table 4

Multiple Linear Regression Equations, Using All Variables, for Predicting Absolute ($l \cdot min^{-1}$) and Relative ($ml \cdot kg^{-1} \cdot min^{-1}$) $\dot{V}O_{2max}$ in Boys, Ages 11 to 14 Years

Variable	Regression Coefficients: Absolute ($l \cdot min^{-1}$)	Regression Coefficients: Relative ($ml \cdot kg^{-1} \cdot min^{-1}$)
Height (inches)	0.067	-0.571
Weight (pounds)	0.008	0.234
Skinfold sum (mm)	-0.024	-0.306
Body mass index	0.061	-1.840
Exercise frequency (days/week)	0.026	0.613
Walk time (sec)	-0.001	-0.032
Postwalk heart rate (b/min)	-0.004	-0.066
(Constant)	-2.165	125.225
R	.90	.84
R^2	.81	.71
SEE	0.287	4.7

Note. N = 67.

Table 5

Multiple Linear Regression Equations for Predicting Absolute VO_{2max} ($l \cdot min^{-1}$) in Boys, Ages 11 to 14 Years

Variable	Regression Coefficients: Number of Independent Variables in Equation 3	2	1
Height (inches)	0.040		0.119
Weight (pounds)	0.017	0.024	
Skinfold sum (mm)	-0.023	-0.031	
(Constant)	-1.330	0.579	-4.802
R	.89	.88	.84
R^2	.79	.77	.71
SEE ($l \cdot min^{-1}$)	0.293	0.302	0.343

Note. $N = 67$.

Equations represent the best coefficient of correlation for the number of retained predictor variables.

equations ($p < .05$), have four or less predictor variables, and yet retain a multiple R of .80 or greater, thus enhancing their practicality in school settings.

Linear equations expressed in $l \cdot min^{-1}$ and $ml \cdot kg^{-1} \cdot min^{-1}$ were identified which explained approximately three-fourths and two-thirds of the variability, respectively. Since a value of $\underline{R}^2 \geq .50$ was set as the criteria for accepting the first hypothesis, it was accepted.

Table 6

Multiple Linear Regression Equations for Predicting Relative $\dot{V}O_{2max}$ ($ml \cdot kg^{-1} \cdot min^{-1}$) in Boys, Ages 11 to 14 Years

Variable	Regression Coefficients			
	Number of Independent Variables in Equation			
	4	3	2	1
Weight (pounds)	0.094			
Skinfold sum (mm)	-0.315	-0.401	-0.436	-0.446
Body mass index	-1.142			
Exercise frequency (days/week)	0.808		0.792	
Walk time (sec)		-0.051		
Postwalk heart rate (b/min)		-0.083		
(Constant)	68.290	93.452	58.865	62.528
$\underline{R}$	.83	.83	.82	.80
$\underline{R}^2$	.69	.69	.67	.64
SEE ($ml \cdot kg^{-1} \cdot min^{-1}$)	4.8	4.8	4.9	5.0

Note. $\underline{N} = 67$.

Equations represent the best coefficient of correlation for the number of retained independent variables.

Using the elapsed time of the shuttle walk and the postwalk heart rate produced poor predictions of maximal oxygen consumption; ($R = .25$, SEE = 0.613 $l \cdot min^{-1}$ and $R = .52$, SEE = 7.2 $ml \cdot kg^{-1} \cdot min^{-1}$). It was the investigator's subjective observation that many subjects increased the speed toward the end of the shuttle walk test, in an effort to lower the elapsed time. This increase in pace, in all probability, resulted in elevating the heart rate in order to meet the increased demands of the exercise. The confounding problem of elevating the heart rate without significantly reducing the total elapsed time of the shuttle walk may have contributed to lowering the predictive accuracy of the shuttle walk protocol. Elapsed time on the shuttle walk was, however, positively correlated with the sum of triceps and subscapular skinfold measurements ($r = .43$, $p < .01$) and body mass index ($r = .36$, $p < .01$). Elapsed time on the shuttle walk was also negatively correlated with relative maximal oxygen consumption, expressed in $ml \cdot kg^{-1} \cdot min^{-1}$ ($r = -.42$, $p < .01$) and exercise frequency ($r = -.25$, $p < .05$). Higher shuttle walk times were therefore associated with lower cardiorespiratory fitness values and lower exercise frequency. It appears that both higher body fat and lower exercise frequency have deleterious effects on walking pace, as well as maximal oxygen consumption ($ml \cdot kg^{-1} \cdot min^{-1}$).

Physical characteristics proved to be strong predictors of absolute maximal oxygen consumption ($l \cdot min^{-1}$). In this study, the suggested equations for the prediction of absolute maximal oxygen consumption exclusively use physical characteristics as predictor variables. Height was highly correlated with maximal oxygen consumption (r = .84).

Although height was a better single predictor of absolute maximal oxygen consumption than weight (r = .84 vs r = .67), the best two predictor equation retained weight and the sum of triceps and subscapular skinfold measurements (R = .88, SEE = 0.302 $l \cdot min^{-1}$). This was despite the insignificant correlation between the sum of skinfolds and absolute maximal oxygen consumption (r = -.01). It appears that the influence of the sum of skinfolds on weight discerned a portion of the total body weight (i.e., fat weight) that did not contribute to absolute maximal oxygen consumption, thereby, improving the prediction.

Similar findings by Mayhew and Gifford (1975) revealed that although none of seven skinfold measurements or their sum were significantly related to absolute maximal oxygen consumption, they emerged as predictor variables in five of six multiple regression equations for predicting absolute maximal oxygen consumption in preadolescent boys (N = 31). Like the present study, the regression coefficients were negative. Dolgener et al. (1990) also found the sum of skinfold measurements (six-site) to be negative regression coefficients, when predicting absolute maximal oxygen consumption in college students (N = 196).

The use of height, weight, and sum of skinfold measurements proved to be the best three variable equation for the prediction of absolute maximal oxygen consumption (R = .89, SEE = 0.293 $l \cdot min^{-1}$). Other multiple regression studies for predicting absolute maximal oxygen consumption in children and youth have produced R values ranging from .48 to .95 (Bonen et al., 1979; Mayhew & Gifford, 1975; Knuttgen, 1967; Metz & Alexander, 1971). The measurement of only simple physical characteristic enhance the practicality of the equations developed in this study for use in schools. It appears that the mass of active tissue is relevant to the prediction of absolute maximal oxygen consumption in 11- to 14-year-old boys.

The sum of triceps and subscapular skinfold measurements was highly correlated with relative maximal oxygen consumption, expressed in $ml \cdot kg^{-1} \cdot min^{-1}$ (r = -.80, SEE = 5.0). Once the prediction of relative maximal oxygen consumption was made using the sum of skinfold measurements, little additional variance could be explained. Increasing the predictor variables from one to three only improved the variance explanation by 5%. The sum of skinfolds probably discerns an amount of active tissue involved in oxygen consumption per unit of body weight. The use of only the sum of two skinfold sites to predict relative maximal oxygen consumption again enhances the practicality of the prediction for use in school settings. It is noted with caution, however, that Krahenbuhl et al. (1977), was unable to find a significant relationship between a six-site skinfold sum and relative maximal oxygen consumption (r = -.33) in 3rd-grade boys (N = 20). The generalization of the relationship between skinfold measurements and relative maximal oxygen consumption to different populations is not advised and further validation is recommended.

Body mass index was also negatively correlated with relative maximal oxygen consumption (r = -.73). Body mass index and sum of skinfolds were highly correlated in this sample, of 11- to 14-year-old boys (r = .85). The influence of body composition on relative maximal oxygen consumption is supported by this study. Early work of Buskirk and Taylor (1957) and Welch et al. (1958), pointed out the negative effect of body fat on relative maximal oxygen consumption and suggested that when maximal oxygen consumption is used to examine the capacity to perform exhausting work, the values should, in fact, be expressed in $ml \cdot kg^{-1} \cdot min^{-1}$.

The best two predictor equation for the prediction of relative maximal oxygen consumption retained exercise frequency as a variable. Exercise frequency was in and of itself, significantly correlated with relative maximal oxygen consumption (r = .24, $p < .05$).

Predictor variables for the best three predictor equation included sum of skinfolds, shuttle walk time, and postwalk heart rate. Compared to the best three predictor equation, the best four predictor equation did not increase the multiple R or lower the SEE. However, the four predictor equation does not require an exercise test, like the three predictor equation, and was presented due to the simplicity of data collection in school settings. Variables retained in the best four predictor equation include sum of skinfolds, exercise frequency, weight and body mass index.

The correlation coefficients from the equations for predicting relative maximal oxygen consumption in this study are generally better than correlation coefficients reported for the relationships between distance runs and relative maximal oxygen consumption in children and youth. In studies of one mile or more, using 20 or more subjects, correlation coefficients typically range from .5 to .8 (Cureton et al., 1977; Jackson & Coleman, 1976; Krahenbuhl et al., 1978; Vodak & Wilmore, 1975). Predictive accuracy in the present study was comparable to a multiple regression procedure, using a multistage 20-meter shuttle run, developed by Mercier et al. (1983), (R = .83 and R = .86, respectively).

Cureton (1973) identified causal factors which differentiated maximal oxygen consumption values. Included were: (a) body weight, (b) body type, (c) skeletal dimensions, (d) ventilation rate, (e) cardiac output,

(f) stroke volume, (g) circulating hemoglobin, (h) diffusion through the lung membranes, (i) oxygen extraction at the cellular level, and (j) relationships with other types of fitness tests. As Mayhew and Gifford (1975) point out, maximal oxygen consumption probably expresses an integration of circulorespiratory capacity and body composition and does not lie at either extreme, but rather occupies some intermediate position. In this study, it was shown that approximately three-fourths of the variance in absolute maximal oxygen consumption and two-thirds of the variance in relative maximal oxygen consumption can be described by simple physical characteristics, emphasizing their practical predictive value in 11- to 14-year-old boys.

The results of this study would indicate that simple physical growth measurements are useful, in school settings, for the prediction of maximal oxygen consumption in 11- to 14-year-old boys. The measurements require little equipment and reliable results are not contingent upon student motivation.

Hypothesis 2

It was hypothesized that, for 11- to 14-year-old boys, there would be no significant difference in postexercise heart rate as measured by telemetry and self-pulse counting. In addition to a paired t test, a correlation coefficient was used to further analyze the relationship.

The heart rates measured by telemetry had a mean of 165.1 beats per minute. The heart rates measured by self-pulse counting, which were measured simultaneously with the telemetrically measured heart rates, had a mean of 144.1 beats per minute. The difference between the two means was 21.0 beats per minute. The standard deviation of the 67 differences was 22.8 beats per minute. The standard error of the difference was 2.8 beats per minute. The calculated $\underline{t}$ value was 7.5 (see Table 7). The analysis resulted in a significance level of $\underline{p} < .001$, which was well below the .05 significance level selected to test the null hypothesis. There was, in fact, a significant difference in postexercise heart rates as measured by telemetry and self-pulse taking, in 11- to 14-year-old boys. Therefore, the null hypothesis was rejected.

Unlike the present study, Best and Steinhardt (1990) found that 5th-grade students could accurately count their own postexercise carotid pulse (5- and 10-second intervals) during physical education classes, although younger children could not. However, low postexercise heart rates were reported, with less than one-fourth of the values higher than 60% of the predicted heart rate reserve. Outliers were also dropped from analysis (M. A. Steinhardt, personal communication, October 31, 1990). Similar to findings in the present study, heart rate counts were generally

Table 7

Paired *t* Test: Heart Rate Via Telemetry and Self-Pulse Counting in Boys, Ages 11 to 14 Years

Variable	*M*	*SD*	*SE*	*t*	2-tail *p*
Heart Rate by Telemetry	165.1	22.0	2.7		
Heart Rate by Pulse	144.1	31.3	3.8		
Difference	21.0	22.8	2.8	7.5	<.001

Note. *N* = 67.

Values are reported in b/min.

underreported. Both studies included a training session on carotid artery palpation and subsequent practice.

The Pearson's product-moment coefficient or correlation for postexercise heart rate's measured via telemetry and self-pulse counting was only $r = .68$. Accurate determination of actual postexercise heart rate from self-pulse counting is not supported by this study. Therefore, it is suggested not to use the self-reported pulse counts of 11- to 14-year-old boys for exercise test values.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

Popular physical fitness test batteries, developed for school use, currently include the 1-mile run/walk test as the field test to estimate cardiorespiratory fitness. However, the validity of distance running performance alone to predict maximal oxygen consumption has been tested in children and youth with mixed results. Although distance running performance may serve a valuable purpose of evaluating physical work capacity in weight-bearing exercise, as well as a whole-body motor skill, it appears to explain only a relatively small portion of the variance of maximal oxygen consumption. The variability among published correlations suggests that predicting individual differences in maximal oxygen consumption from distance run performance only is suspect. Investigators have improved on the prediction of maximal oxygen consumption, in children and youth, using multiple regression approaches (Bonen et al. 1979; Mayhew & Gifford, 1975; Mercier et al., 1983). This procedure provides better predictive accuracy, apparently because several variables are statistically combined to account for maximal oxygen consumption variation.

The use of multiple linear regression analysis for the prediction of maximal oxygen consumption was further pursued in this study. The use of practical field measurements, which could be collected in school settings, was of interest. Predictor variables garnered from a shuttle walk protocol, physical characteristics, and exercise frequency were all considered in the predictor equations. Predictor variables, in this study, did not require a maximal physical effort and, thus, removed the student motivation aspect.

A volunteer sample of 67 boys, ages 11 to 14 years, was studied for the primary purpose of investigating the use of a shuttle walk protocol, in combination with other selected field measurements, for predicting maximal oxygen consumption. Specifically, the following predictor variables were considered in the development of the prediction equations: (a) elapsed time on an 800-yard shuttle walk, (b) telemetrically measured postexercise heart rate (following the shuttle walk test), (c) height, (d) weight, (e) sum of triceps and subscapular skinfold thicknesses, (f) body mass index, and (g) days per week of physical activity that elicits sweating and hard breathing for 20 minutes or more.

Oxygen consumption was measured during a graded exercise test performed on a motorized treadmill. Subjects exercised to a point of volitional fatigue. Maximal oxygen consumption values, expressed in $l \cdot min^{-1}$ and $ml \cdot kg^{-1} \cdot min^{-1}$, were used as dependent variables. Stepwise multiple linear regression analysis was used to identify the most appropriate prediction equations.

Although the accuracy of self-pulse counting has been validated in adult populations, little is known about the ability of children and youth to accurately count their own pulse following exercise. Best and Steinhardt (1990) found that 5th-grade students could accurately count their own postexercise carotid pulse (5- and 10-second intervals), following an instructional session and practice, whereas younger children could not. Accordingly, this study also investigated the difference between postexercise heart rates, measured via telemetry and self-pulse counting, by 11- to 14-year-old boys. Heart rates were simultaneously measured by telemetry and self-pulse counting following an 800-yard shuttle walk. A paired $\underline{t}$ test and a Pearson's product-moment coefficient of correlation were used in the analysis.

The remainder of this chapter is comprised of three sections. The first section states the findings of this study based on the hypotheses tested. Conclusions are summarized in the second section. Recommendations are summarized in the last section.

Hypotheses

Two hypotheses were tested in this study. Acceptance of the first hypothesis was based on explaining one-half or more of the variability when predicting maximal oxygen consumption in boys ($\underline{R}^2 \geq .50$). The second hypothesis was tested at the .05 level of significance.

Hypothesis 1

Linear combinations of predictor variables including: (a) elapsed time on a shuttle walk of 800 yards, (b) telemetrically measured postexercise heart rate following the shuttle walk test, (c) height, (d) weight, (e) sum of triceps and subscapular skinfold thicknesses, (f) body mass index, and (g) days per week of physical activity that elicits sweating and hard breathing for 20 minutes or more were identified which accurately predict maximal oxygen consumption in 11- to 14-year-old boys (expressed in both $l \cdot min^{-1}$ and $ml \cdot kg^{-1} \cdot min^{-1}$).

Hypothesis 2

There was a significant difference in telemetrically measured postexercise heart rates and postexercise heart rates measured by self-pulse counting in boys, ages 11 to 14 years.

Conclusions

Based upon the results of this study the following conclusions were drawn:

1. The ability to predict maximal oxygen consumption, in 11- to 14-year-old boys, from only the elapsed time on an 800-yard shuttle walk and postwalk heart rate is poor.

2. Accurate prediction of absolute maximal oxygen consumption ($l \cdot min^{-1}$), in 11- to 14-year-old boys, can be made from simple physical characteristics (i.e., height, weight, and sum of triceps and subscapular skinfold measurements).

These variables can be garnered in the school setting by simple field measurement methods.

3. Accurate prediction of relative maximal oxygen consumption ($ml \cdot kg^{-1} \cdot min^{-1}$), in 11- to 14-year-old boys, can be made simply from the sum of triceps and subscapular skinfold thicknesses. This variable value can be garnered in the school setting by simple field measurement methods.

4. Postexercise heart rate monitoring via self-pulse counting, by 11- to 14-year-old boys, is poor.

Recommendations

Based upon the results of this study, the following recommendations are presented:

1. School physical education programs provide a unique opportunity to facilitate the attainment of national health and physical fitness objectives for children and youth. Assessment of physical fitness levels in student populations, using accurate and appealing field methods, should be further pursued in research and used by the practitioner. School personnel responsible for assessment of physical fitness should be adequately prepared in measurement methodology, interpretation skills, and intervention strategies, in order to implement such programs in the school curriculum. School administrators should ensure that comprehensive school health education programs are implemented which promote healthy lifestyles and reduce student health risks. Plans should include the integration

of curriculum, school environment, and health services to reinforce healthy lifestyles and health risk reduction. The systematic evaluation of overall effectiveness should be an integral component of these programs.

2. Further studies should be conducted for the purpose of validating the use of easily measured physical growth characteristics in the prediction of maximal oxygen consumption in children and youth, including both sexes and all ages. Practical applications for school settings should be considered.

3. Further studies should be conducted for the purpose of determining the contributions of body composition and body type to maximal oxygen consumption in children and youth.

4. If accuracy of postexercise heart rate is paramount, measurement by methods other than self-pulse counting is recommended.

5. Further studies should be conducted for the purpose of determining if effective methods of teaching self-pulse counting exist for children and youth. Practical applications for school settings should be considered.

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APPENDIX A

May 14, 1990

Dear Parent:

The value of physical activity for control of obesity, heart disease, and other health problems has been cited in numerous professional and government reports. The roots of heart disease and other degenerative diseases are related to the development of childhood behavior patterns. Therefore, youth fitness has become a national concern. Of particular concern is the participation, by youth, in vigorous physical activities that promote the maintenance of cardiorespiratory fitness (which involves the efficient functioning of the heart, lungs, blood, and muscles).

As part of my research for a doctorate degree in education, I am investigating a practical, alternative method that physical education teachers can use to estimate the cardiorespiratory fitness levels in boys. Specifically, this study will determine if the elapsed time of an 800 yard shuttle walk, post walk heart rate, height, weight, skinfold measurements, and self reported exercise habits are good predictors of cardiorespiratory fitness in 11-to-14-year-old boys (as determined by direct laboratory exercise testing).

Sixty volunteer boys, age 11 to 14, will be recruited for this study. It is not my intention to exclusively recruit athletes. The testing procedures are designed to accommodate boys at various levels of physical fitness. Application will not guarantee selection, due primarily to the limit in the number of subjects. Testing will be conducted at Allen Memorial Hospital. It is anticipated that most of the testing will be conducted during the summer months. Each subject will be able to complete the instruction and testing in approximately two hours.

Project approval has been granted by the University of Northern Iowa and the Waterloo Community School District. Some selected volunteer boys, who attend Logan Intermediate School, may be tested during the regular school day. Others will be tested while school is not in session.

Enclosed are the following application forms, which must be completed prior to participation in the study:

1) Participant Information Sheet
2) Physical Activity Readiness Questionnaire
3) Informed Consent Form

Data obtained from this study will be utilized for analysis purposes only and any personal information will not be released to anyone other than investigators without permission from the participant and a parent or legal guardian.

If your son wishes to participate in this study and you approve of his participation, please return the completed forms to:

Loran Erdmann, M.A.
Allen Wellness Center Director
Allen Memorial Hospital
1825 Logan Avenue
Waterloo, Iowa 50703

Logan Intermediate School students may return the forms to Mr. DeWaard.

If your son is selected for participation in this study, he will be notified for appointment scheduling. Some selected volunteer boys, who attend Logan Intermediate School, may be scheduled for testing during regular school hours.

By participation in this study, your son will be providing valuable information which can be used to better understand methods of testing physical fitness levels in youth. He will also have an opportunity to learn more about sports science and his own physical fitness.

I appreciate your consideration regarding the participation of your son in this research project. If you have any questions, please do not hesitate to call me at 235-3615 (work) or 277-4660 (home).

Sincerely,

Loran Erdmann, M.A.
Allen Wellness Center Director
Allen Memorial Hospital
1825 Logan Avenue
Waterloo, Iowa 50703

Enclosures (3)

APPENDIX B

PHYSICAL ACTIVITY READINESS QUESTIONNAIRE

Please answer the following questions about the potential participant by circling the correct responses. After completion, this form must be signed by both the participant and a parent or legal guardian.

Yes No 1. Has a doctor ever said that he has heart problems? If yes, please comment.

Yes No 2. Does he frequently suffer from pains in his chest? If yes, please comment.

Yes No 3. Does he often feel faint or have spells of severe dizziness? If yes, please comment.

Yes No 4. Does he have diabetes? If yes, please comment.

Yes No 5. Does he have asthma or other breathing difficulties? If yes, please comment.

Yes No 6. Does he have a bone or joint problem that may be aggravated by walking or running? If yes, please comment.

Yes No 7. Does he have restrictions placed on his participation in school physical education and/or athletic programs due to chronic health problems or physical limitations? If yes, please comment.

____

Yes No 8. Is there a good physical reason, not previously mentioned, why he should not participate in vigorous exercise involving walking and running? If yes, please comment.

____

Yes No 9. Is he taking any medications? If yes, please comment by listing medication(s), dosage(s), and medical reason(s).

medication	dosage	medical reason

______________________________ (signature of subject) ______________ date

______________________________ (printed name of subject)

______________________________ (signature of parent or legal guardian) ______________ date

______________________________ (printed name of parent or legal guardian)

APPENDIX C

INFORMED CONSENT

After reading this informed consent form, it must be signed by both the participant and a parent or legal guardian.

Title or Research: "Validation of a Shuttle Walk Test to Estimate Maximal Oxygen Consumption in 11-to-14-Year-Old Boys"

Principal Investigator: Loran D. Erdmann, M.A.
Allen Wellness Center Director
Allen Memorial Hospital, 235-3615

Explanation of Test: The purpose of this study is to determine if the elapsed time of an 800 yard shuttle walk, post exercise heart rate, height, weight, skinfold measurements, and exercise habits are good predictors of maximal oxygen consumption (an indicator of cardiorespiratory fitness or endurance) in 11-to-14-year-old boys. Secondly, pulse taking accuracy will be assessed. Participants will be timed in an 800 yard shuttle walk (with a turn in every 20 yards). Post exercise heart rates will be measured by electrocardiogram and self pulse taking. Height, weight, and skinfold thicknesses will be measured. Subjects will also be asked about their exercise habits. Maximal oxygen consumption will be measured by analysis of expired gases collected during a graded exercise test, performed on a motorized treadmill. The exercise intensities will increase in stages, by increasing the speed and/or elevation of the treadmill. The investigators may stop the test at any given time because of signs of fatigue or the participant may stop when he wishes because of personal feelings of fatigue or discomfort.

Risks and Discomforts: During testing, the participant is expected to perform at or near maximal effort and may experience temporary short of breath, as well as fatigue. There exists the possibility of certain changes occurring during testing. They include abnormal blood pressure, fainting, disorders of the heart, and in very rare instances, heart attack. These risks are extremely small, particularly in young people. Effort will be made to minimize these by observations during testing. Emergency equipment and trained personnel will be available to deal with unusual situations which may arise.

Participation in this study is voluntary and may be discontinued at any time. Participants, as well as a parent or legal guardian, have the right to ask any questions about the study and are encouraged to seek explanations about any phase of the testing procedures that is unclear. Data obtained from this study will be utilized for analysis purposes only and any personal information will not be released to anyone other than investigators without permission from the participant and a parent or legal guardian. If you have any questions about the research or your rights as a subject, you may contact the University of Northern Iowa Graduate College office at 273-2748.

We (subject and a parent or legal guardian) are aware of the nature and extent of the participation in this project, as stated above, and the possible risks arising from it. We (subject and a parent or legal guardian) hereby agree to the participation of the subject in this project. We (subject and a parent or legal guardian) acknowledge that we have received a copy of this informed consent form.

________________________________ ____________
(signature of subject) date

____
(printed name of subject)

________________________________ ____________
(signature of parent or legal guardian) date

____
(printed name of parent or legal guardian)

________________________________ ____________
(signature of investigator) date

____
(printed name of investigator)